African Crop Science Journal, Vol.1, No. 2, pp. 81–85, 1993
Printed in Kenya.

1021-9730/93 $ 10.00 + 0.00

INHERITANCE AND HERITABILITY OF HEAT TOLERANCE IN SEVERAL SORGHUM CULTIVARS DURING THE REPRODUCTIVE PHASE.

B. W. KHIZZAH, F. R. MILLER[1], and R. J. NEWTON[2]
Texas Agricultural Experimental Station, Route 3, Box 219, Lubbock Texas 79401.
[1]Soil and Crop Science Department, Texas A&M University, College Station, Texas.
[2]Department of Forest Science, Texas A&M University, College Station, Texas 77840-2474.

(*Received* 13 *January* 1993; *accepted* 20 *August* 1993)

ABSTRACT

Four sorghum parental lines, RTx430, BTx3197, RTx7000, and B35 and their F_1 and reciprocals, and F_2 progenies were evaluated during their reproductive phases to access the genetic basis of heat tolerance. Heat tolerance was measured under field and greenhouse conditions at College Station, Texas during 1990. Parental cultivars were significantly more heat tolerant than their hybrids. Inheritance of heat tolerance appeared to be associated with two genes with dominant and recessive epistatic effect influenced by maternal effects. Broad sense heritability values were low to moderate due to large environmental effects which may complicate direct selection. B35 was shown to be useful for improvement of heat tolerance.

Key Words: **Heat tolerance, heritability, inheritance, *Sorghum bicolor***

RÉSUMÉ

Quatre lignées parentales de sorgho, RTx430, BTx3197, RTx7000, et B35, et les descendances F_1 et F_2 de leurs croissements réciproques ont été évaluées pendant leur phase reproductive afin d' analyser la base génétique de la tolérance de chaleur. En 1990, la tolérance à la chaleur a été mesurée en champs et en serres à College Station, Texas. Les cultivars parentaux étaient significativement plus tolérants que leurs hybrides. L'héridité de la tolérance à la chaleur est probablement associée à deux gènes épistatiques qui ont un effet dominant et récessif influencé par la nature du parent maternel. Les valeurs d'héréditité au sense large étaient peu élevées ou médiocres à cause des effets de l'environnement qui compliquent la sélection directe. Les résultats ont montré que la lignée B35 peut être utilisée pour améliorer la tolérance de sécheresse.

Mots Clés: **Tolérance à la chaleur, hérédité, *Sorghum bicolor***

INTRODUCTION

Most of the world's grain sorghum (*Sorghum bicolor* L. Moench) production occurs in arid or semi-arid climates without supplementary irrigation. Drought of variable duration and intensity often associated with above average temperatures in these regions is the major cause of low grain yield.

Cellular dehydration causes significant disorders in membrane structure, composition, and function (Poljakoff-Mayber, 1981), or gives rise to a phenomenon known as 'leaf firing' (Peacock, 1979; Jordan and Monk, 1980). At the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), sorghum is screened for heat tolerance when leaf and air temperatures reach 43°C and 55°C, respectively, allowing leaf firing to occur in susceptible cultivars (Seetharama *et al.*, 1982).

Genetic variability for heat and desiccation tolerance exists in sorghum (Sullivan and Blum, 1970; Blum and Ebercon, 1976; Sullivan *et al.*, 1977; Sullivan and Ross, 1979; Jordan and Sullivan, 1982). Jordan and Sullivan (1982) illustrated the feasibility of genetic manipulation for heat tolerance, and they noted that some parents in hybrid combinations were consistently tolerant or susceptible. No further work on inheritance of heat tolerance has since been reported for sorghum. Understanding the genetic control of heat tolerance in sorghum is a necessary step in formulating an appropriate breeding programme. The objective of this study was to determine the mode of inheritance of heat tolerance among selected sorghum cultivars.

TABLE. 1. Description of four sorghum inbred cultivars used to study heat tolerance, 1990.

	Field Reaction		
Cultivars	Early drought	Late drought	Heat tolerance[a]
RTx430	good	good	fair
BTx3197	good	fair	very good
RTx7000	very good	very poor	very poor
B35	very poor	very good	good

[a]Based on electrical conductivity ratings (Khizzah, 1991).

MATERIALS AND METHODS

Four sorghum inbred cultivars (Table 1) provided by Dr. F. R. Miller of Texas A&M University/ Texas Agricultural Experimental Station were used in this investigation. These cultivars were chosen for their contrasting post-flowering drought resistance (Rosenow, 1991; Miller, 1991, pers. comm.).

Hand emasculated crosses were made between these cultivars following a full diallel mating system. The parents, F_1, and F_2 were evaluated both in the field and in the greenhouse at College Station, Texas during 1990, using a randomized complete block design with three replications. Heat tolerance was measured on 20 plants during anthesis, following the method of Sullivan (1972). Twenty one-cm leaf discs were cut from the second leaf below the flag leaf from each cultivar with a cork borer, placed in a test tube and thoroughly washed with distilled water for 3 hr, and changing the water four times. At the end of the washings, enough water was left to keep the discs wet during the heating treatments. The tubes were covered with plastic wrap and placed in a water bath for 1 hr at 48°C. A duplicate sample at room temperature served as a control. After heating, 30 ml of distilled water was added to each tube and incubated overnight at 10°C. Relative amounts of electrolyte diffusing from the leaf tissues were measured with a conductivity bridge and dip cell (YSI MODEL 32, Yellow Springs Instrument Co., Ohio, USA) after equiliberating the tubes at 25°C. After the first conductivity reading was taken, the tubes were again covered

TABLE 2. Mean percentage cell damage of parents and their F_1 progenies grown in the field during the summer of 1990 at College Station, Texas[a].

Pedigree	% Cell Damage	Pedigree	% Cell Damage
RTx430*RTx7000	87.4a	RTx7000*BTx3197	77.8ab
BTx3197*B35	85.9a	RTx7000*B35	77.0ab
B35*RTx7000	85.4a	BTx3197*RTx7000	75.5ab
RTx7000*RTx430	84.6a	RTx7000	72.9ab
RTx430*B35	84.6a	RTx430*BTx3197	65.6b
B35*BTx3197	82.6a	RTx430	64.7c
BTx3197*RTx430	81.6a	B35	47.8c
B35*RTx430	78.3ab	BTx3197	39.5c

[a]Data are means of three replicates and values within the column followed by the same letters do not differ significantly ($P \leq 0.05$).

TABLE 3. Parental phenotypes and suggested genotypes with theoretical expectations for crosses made with heat tolerant cultivar B35 and three other cultivars of grain sorghum

Parents	Combinations		Theoretical expectation	
	Phenotype	Genotype	F_1	F_2
RTx7000	Susceptible	$Hs_1Hs_1Hs_2Hs_2$	0:1	3:13
RTx430	Susceptible	$hs_1hs_1Hs_2Hs_2$	0:1	3:13
BTx3197	Tolerant	$Hs_1Hs_1hs_2hs_2$	1:0	13:3
B35	Tolerant	$hs_1hs_1hs_2hs_2$	–	–

TABLE 4. Segregation ratios and broad sense heritability for heat tolerance in F_2 progenies derived from diallel crosses between three sorghum cultivars grown in both the field and a greenhouse during the summer of 1990 at College Station, Texas

Crosses/location	F_2 Ob*	F_2 Ex	Chi²	Broad sense heritability
BTx3197*B35 Gh †	6:50**	10.5:45.5	1.875	0.09
Fld	4:96	18.75:81.25	0.979	
B35*RTx430 Gh	14:31	8.44:36.56	3.734	0.76
Fld	20:80	18.75:81.25	0.081	
B35*RTx7000 Gh	12:40	9.75:42.25	0.387	0.55
Fld	14:76	16.88:73.13	0.240	

*Ob, = Observed, Ex = Expected and $Chi^2 = (|Ob\ resistant - Ex\ resistant| - 0.5)^2 / Ex\ resistant + (|Ob\ susceptible - Ex\ susceptible| - 0.5)^2 / Ex\ susceptible$.
**, Resistant : susceptible ratio where resistant = 45% or less cell damage and susceptible > 46% cell damage, respectively.
† Gh = greenhouse, and Fld = field.
|, = absolute or positive value of the difference

with plastic wrap, and samples were killed by heating in a water bath at 90°C and cooling to 25°C before the conductivity was re-measured. Injury value was estimated from the elevated temperatures and was calculated as a percentage increased conductance over the controls. This calculation accounted for injury to the control by the cutting and handling process.

Analysis of variance was performed to show differences in reaction to heat among cultivars and their F_1 progenies. Paired mean tests were used to detect cytoplasmic effects between reciprocal crosses. F_1 and parental means were compared to detect additive/dominance relationships. Frequency distribution of F_2 populations of crosses made with B35 were used to estimate the number of genes. Pearson's Chi-square test of goodness-of-fit was used to test validity of assumptions. Variance partitioning was performed using SAS (SAS Institute Inc., 1985) to generate variances associated with each mean, and in determination of genotypic, additive, dominance, and environmental components. These were used in the estimation of heritability.

RESULTS AND DISCUSSIONS

Significant differences among pedigrees were revealed for heat tolerance ($P \leq 0.01$), and the coefficient of variation (CV) was low (11.9%). Percent cell damage ranged from 40 in BTx3197 to 87 in RTx430*RTx7000 (Table 2). Similar ranges have been reported (Jordan and Sullivan, 1982). Inbred cultivars were more heat tolerant compared to their F_1 progenies. Also, cultivars which had good late season-field drought tolerance appeared to be heat tolerant, suggesting a possible relationship between drought and heat responses. B35*RTx430, B35*RTx7000 and RTx430*BTx3197 crosses differed from their reciprocals ($P \leq 0.05$), suggesting cytoplasmic effects for heat tolerance. This was not observed in the remainder of the crosses. Reciprocal crosses were combined to increase sample size. Using the F_2 frequency distribution for the crosses with B35, the following assumptions were made: (a) two loci were responsible for expression of heat tolerance, and (b) complete dominance at both gene pairs, but one gene when dominant is epistatic to the other. Using these assumptions, the parental phenotype and genotypic combinations and the theoretical expectations for the crosses are given in Table 3. The Chi-square test of goodness-of-fit for the validity of these assumptions (Table 4) conforms to the expectations. It was proposed that heat tolerance was under the control of two genes with a simple additive model and epistatic interaction, but further testing including backcrosses and F_3 is necessary to confirm the number of genes.

Broad sense heritability ranged from 0.09 in the cross between resistant lines B35*BTx3197 to 0.76 in the cross between resistant B35 and susceptible RTx430; a value of 0.55 was observed for B35*RTx7000. Low heritability was associated with low F_2 and high parental variances. Heritability values close to these (0.83 and 0.69) have been reported for rice, *Oryza sativa* (Mackill and Coffman, 1983) and common bean, *Phaseolus vulgaris* (Schaff, 1985). The presence of low to high heritability in these data suggests the possibility for improvement of sorghum cultivars for heat tolerance. Both B35 and BTx3197 could be used as sources for heat resistance in an improvement programme.

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